

**SEDIMENT PROFILES AND HYDROLOGICAL IMPLICATIONS
FOLLOWING HURRICANE HARVEY FOR MISSION RIVER IN TEXAS**

An Undergraduate Research Scholars Thesis

by

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ABSTRACT

Sediment Profiles and Hydrological Implications Following Hurricane Harvey for Mission River in Texas

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New and continuing research within recent years has provided volumes of insight into the past, present, and projected states of the Texas coastal region, its ecosystems, climate patterns, and human population. The Mission River in Texas and its surrounding geographic area are an important component to this area of research with regards to its hydrological regime and underlying influences, including potential factors of disturbance such as land use and land cover (LULC), impacts from flooding events, and high-magnitude tropical cyclones. The design of this study consists of two major components: (1) perform sediment/soil core sampling for physical properties with an emphasis on soil texture to determine the agreement with previously-sampled data provided by the Natural Resources Conservation Service Soils Database (SSURGO); and (2) infer the environmental factors that have attributed to any changes in soil texture and other physical properties. Changes in the sediment profiles of the Mission River are expected due to the observation of such influences in the geographic area following the previous survey, including LULC alterations from human activity, frequent flooding, and impacts following the recent landfall of Hurricane Harvey in late-August 2017.

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NOMENCLATURE

ESP	PN150 JMC Environmentalist's Sub-Soil Probe
LULC	Land-use and land-cover
MACR	Mission-Aransas Coastal Region
M-A NERRS	Mission-Aransas National Estuarine Research Reserve System
NOAA	National Oceanic and Atmospheric Administration
NRCS	National Resources Conservation Service
SSURGO	Soil Survey Geographic Database
TNRIS	Texas Natural Resources Information System

CHAPTER I

INTRODUCTION

Background of the Mission River Basin

The Mission River in Texas is a coastal river part of the Mission-Aransas coastal region (MACR) in south Texas. The area is particularly prone to sea level rise and land subsidence, upstream land-use and land-cover (LULC) changes, and population increase. In addition, low-magnitude flooding events dominate its hydrological regime (Richter and Richter, 2000), and changes in storm patterns resulting from climate change increases particularly with regards to tropical cyclone magnitude and destructiveness (Emanuel, 2005) – all of which may affect local hydrological regimes, ecosystem health, and biodiversity (Güneralp et al., 2014). The encompassing Mission-Aransas National Estuarine Research Reserve (NERR) site, supported by the National Oceanic and Atmospheric Administration (NOAA), was also established under the premise of determining and understanding the causes and impacts of natural and anthropogenic-induced changes in estuarine ecosystems, as well as the effects of climate change that include “potential loss of habitats and associated species, as well as adverse impacts to local economies, development, and infrastructure” (Mission-Aransas NERR, 2017).

The MACR has, within recent decades, been subject to the impacts of anthropogenic activity and LULC alterations, largely central to streams and rivers, estuaries, bays, and urban centers (Güneralp et al., 2014). The area’s land-use distribution is highly complex, including smaller urban centers, agriculture, woodlands, and wetlands (Evans et al., 2012). Projections in climate change, sea level rise, and various human-induced pressures on coastal riparian zones are currently a topic of consideration with regards to the quality and health of their ecology (Davis

and Smith, 2013), in addition to their pressures on water resources (Stromberg, 2001). However, Mission River is minimally altered by human activity in contrast to many other rivers because it has not been subject to the construction of dam reservoirs or surface water withdrawals. The outcome of this study is to advance the current understanding of riparian zones by expanding knowledge of the contemporary soil profile of the Mission River riparian zone, its resulting subsurface flows and groundwater hydraulic characteristics, and the sedimentological implications of coastal conditions and how they are impacted by human activity and extreme weather events.

Human Impact and Land Use and Land Cover Changes

Agriculture and Livestock Grazing

The MACR is a region abundant in agricultural activity. The conversion of forests to agricultural cover and roadway development can decrease rates of soil infiltration and increased flooding, headward erosion and incision of stream channels, and floodplain isolation (Poff et al., 1997).

Vegetation has an essential role in maintaining soil stability and infiltration rates, limiting the area of exposed soil, and mitigating the impact of rain splash (Pearce et al., 1998; Bear et al., 2012). Cattle grazing is well-known to cause declines in vegetative cover and, consequently, wind and runoff erosion of sediments (Li et al., 2007). This occurs primarily due to the increase of bare ground that becomes exposed when vegetation, which otherwise decreases aquatic sediment amounts and nutrient loading, is removed from grazing (Haan et al, 2006). As a result, within watershed and riparian systems, higher amounts of cattle grazing are associated with higher amounts of riparian degradation (Grudzinski et al., 2016). Moreover, cattle also impact sediment amounts within a river flow by spending time in stream ponds, which contributes to the resuspension of sediments in the bed load (Grudzinski et al., 2016).

Overgrazing in a prairie area, such as that of the MACR, poses a particular threat to more sensitive vegetation species and the ecosystem's biodiversity (UTMSI, 2006). Grazing management policies have been implemented by the Fennessey Ranch, which includes a portion of the Mission River, in recent years to avoid overgrazing and overstocking in order to maintain food and land cover, as well as to improve local habitats. In doing so, riparian zones were fenced off and no-grazing zones were established to prevent trampling and to maintain and recover vegetation (University of Texas Marine Science Institute, 2006).

Urbanization

Landscape transition to urban land cover has been observed to have notable impacts on riparian system geomorphology, hydrology, and sedimentology, particularly due to erosional processes. A channel reduction pattern is particularly apparent in tropical climates due to their characteristic intensity of precipitation and highly-weathered soils (Chin 2007). The commencement and construction of urban land cover yields a marked increase in the magnitude and frequency of flooding events (Hammer 1972); the impermeable nature of urban land cover reduces soil infiltration and instead redirects precipitation to overland flow and storm drains. Moreover, sediment production in construction stages of urbanization have been noted to increase by two to ten times pre-development yields; consequences of these processes primarily encompass stream bank erosion and channel widening (Chin 2007). Although sediment yield sharply declines following the later stages of urbanization and the completion of construction of urban areas because of pavement cover, highways and urban activities continue to introduce significant quantities of particulates into runoff sourced from precipitation events (Oyegun, 1994). Post-construction phases of urbanization are also characterized by changes in flooding dynamics of runoff: patterns in lag time, flood frequency, and runoff volume, yielding larger and more frequent floods (Chin 2006; Leopold 1968).

Groundwater Pumping

Groundwater pumping lowers subsurface water tables, thereby reducing the stability of vegetation populations. This can in turn cause bank erosion and channel downcutting (Kondolf & Curry, 1986). Land subsidence may also occur as a result of groundwater extraction, particularly due to the presence of clay layers with low permeability and high porosity.

Flooding Impact

Flooding plays a role in both local human population natural hazard management and ecosystem health; the connection of a river's riparian zone to the channel maintains the river's ecological integrity. The concept of the "effective discharge level" has been noted to be the dominant condition of fluvial geomorphological change with regards to sediment transport; high-frequency low-to-intermediate flow conditions over time contribute to the bulk of sediment transport related to processes of erosion and sedimentation (Richter and Richter, 2000; Wolman and Miller, 1960; Williams, 1978; Andrews, 1980; Leopold, 1994; Rosgen, 1996). Sediment within a riparian zone can be transported by flooding events downstream or upstream, yielding variations in the characteristics of the soil profile (Richter & Richter, 2000).

Hurricane Impact: Hurricane Harvey and Future Storms

Atlantic cyclones have historically been recognized for the changes that they bring to sediment transport processes and soil profile characteristics within coastal riparian zones and estuarine environments. Hurricanes and tropical storms that impact coastal riparian zones yield increased erosion and transport of fluvial sediments downstream, as well as strongly affecting resuspension of sediments in their respective estuarine environments (Sommerfield et al., 2017). Consequently, erosional and/or depositional effects can occur during a tropical cyclone in coastal fluvial systems.

The recent impact of Hurricane Harvey on the Texas coast may function as a model case for severe Atlantic tropical storms and their implications for coastal riparian zones in addition to their respective sedimentological and hydrological properties. Climate projections for the Atlantic Basin predict more intense and frequent tropical cyclone events (Elsner et al, 2008) as a result of observed patterns in climate change; thus, the relationship between tropical cyclones

and their impacts to coastal riparian zones is an important topic of study within the hydrological and geomorphological sciences, in addition to natural hazard management.

CHAPTER II

METHODS

Sediment Sampling and Analysis

Collection of sediment samples from various locations within the Mission River riparian zone entailed the use of a PN150 JMC Environmentalist's Sub-Soil Probe (ESP) to collect sediment samples from the surface and sub-surface. Sampling locations were selected based on previously-sampled vegetation transects measured at identified locations as follows: FR-0, FR-9, FR-11, FR-12, FR-13, FR-19, FR-21, and FR-25 (Davis, Smith 2013). Soils were gathered and distributed based on length from the surface; 0-0.3 meters characterized as surface sediments, and 0.3 meters-below as sub-surface sediments. Preserved horizon samples were then extracted using the PN150 JMC ESP for visual analysis for its respective sampled location in order to integrate depth and boundary variability (Schoenberger, 2012).

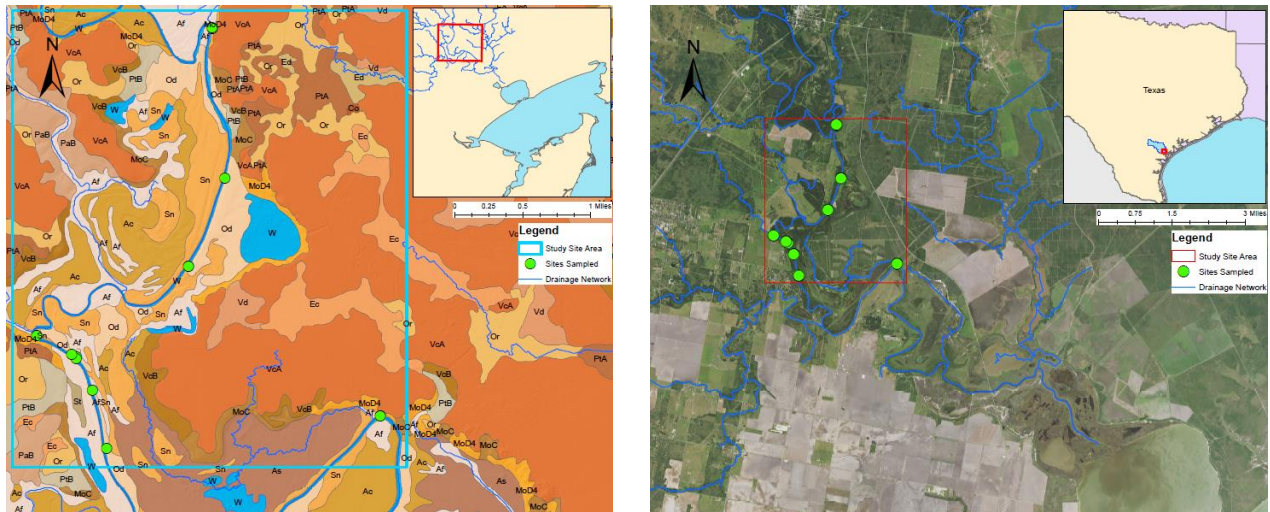


Figure 1. Study site and sampled sediment locations of Mission River, Texas and distribution of soil types within the study area (NRCS). The riparian zone within the study site is predominantly

comprised of a highly variable distribution of Aransas Clay, Sinton Sandy Clay Loam, Odem Fine Sandy Loam, Victoria Clay, and Papalote Fine Sandy Loam.

Surface and sub-surface sediments were submitted to Texas A&M University AgriLife Extension Service's Soil, Water and Forage Testing Laboratory for pH, NO₃-N, Conductivity, Mehlich III, and Texture analyses (Schofield, 1955; Keeney, Nelson, 1982; Kachurina et al, 2000; Rhoades, 1982; Mehlich, 1984; Day, 1965; Murphy, Riley, 1962).

Preserved horizon cores were visually analyzed to identify horizon layers and sedimentary formations, as well as stratification of organic matter content and soil texture variability. Identified surface and sub-surface layers were then appended to results from laboratory analyses.



Figure 2. Photos taken on February 20, 2018. Fieldwork use of the sub-soil probe (PN150 JMC Environmentalist's Sub-Soil Probe) and Trimble GPS point equipment.

Geographic Information Systems Data

Previously-surveyed sedimentological data and aerial imagery were obtained from the National Resources Conservation Service (NRCS) and Texas Natural Resources Information System (TNRIS) databases and integrated into a Geographic Information Systems (GIS) environment (ArcGIS 10.4 in this case). This was carried out to observe and account for any alterations to the Mission River as a result of Hurricane Harvey's impact, visualization of dead and downed vegetation that may alter the riparian zone's sedimentology, and the identification of formations resulting from flooding events.

CHAPTER III

RESULTS

Sediment Sample Analysis

Sediment profiles collected displayed homogeneity among layers, ranging from clays to medium sands. Fine and medium sand layers overlaying clay and silty loam layers, characteristic of flooding events, were evident in many of the cores taken. Some sites displayed recent sand deposits in surface layers: FR-0, FR-13, FR-19, FR-23, FR-25, and FR-26.

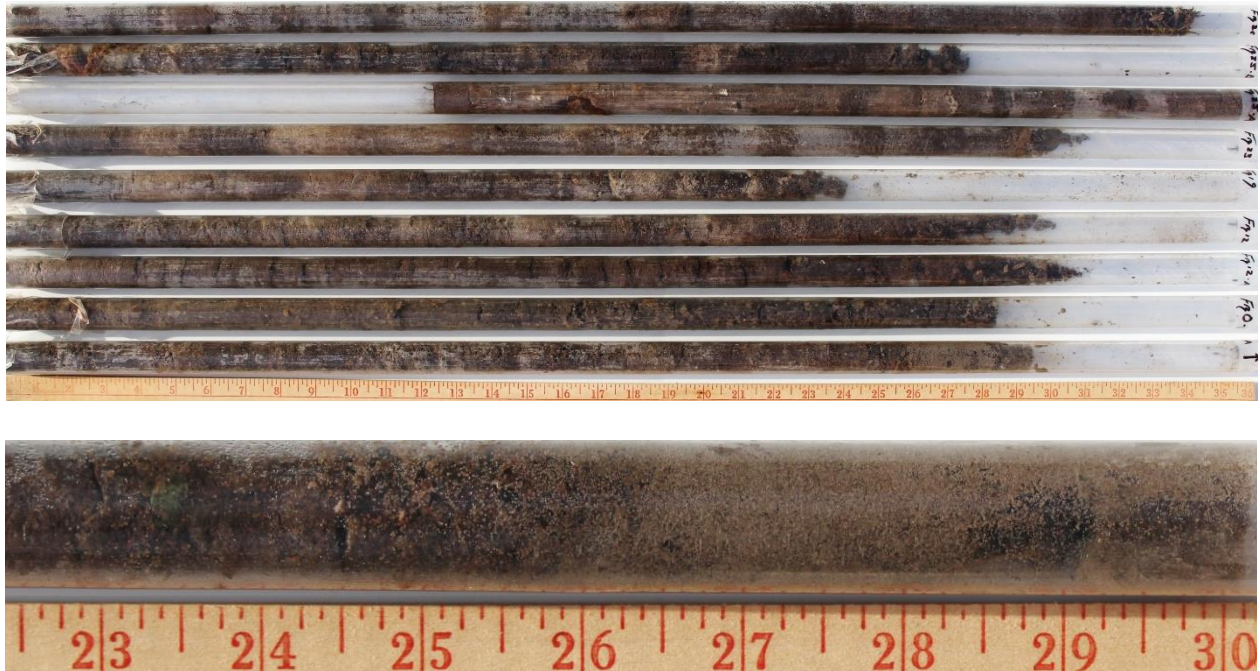


Figure 3. Preserved horizon sediment cores, upstream to downstream. Samples display variability in layers of clays, silty loams, and fine sands in addition to organic matter content and vegetation roots. Zoomed to FR-0 displaying surface-layer sandy flood deposit above clay and silty loam layers.

Geographic Information Systems and Field Observations

SSURGO data on sampled locations indicated a variability in flooding and topography, particularly with respect to slope. Sampled locations were primarily comprised of fine sandy loams and clays.

Figure 4. Sampled sites were identified based on their soil classifications in accordance to SSURGO database results within a Geographic Information Systems environment.

Sites Sampled	SSURGO Class Key and Description	
FR-0	MoD4	Monteola clay, 5 to 8 percent slopes, gullied
FR-9	Od	Odem fine sandy loam, occasionally flooded
FR-11	Af	Aransas clay, frequently flooded
FR-12	Od	Odem fine sandy loam, occasionally flooded
FR-13	Sn	Sinton sandy clay loam, 0 to 1 percent slopes, occasionally flooded
FR-19	Od	Odem fine sandy loam, occasionally flooded
FR-21	Od	Odem fine sandy loam, occasionally flooded
FR-25	MoD4	Monteola clay, 5 to 8 percent slopes, gullied

Figure 5. Soil geomorphological description and representative weight percentage of composition of sands to organic matter content for sampled location types (NRCS). Odem fine sandy loam is distinct due to its higher weight percentage of medium and fine sands and lower weight percentage of clay.

Class	Geomorphology	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Coarse Silt	Fine Silt	Clay	Organic Matter
Af	flood plains on river valleys on coastal plains	2.88	3.4	4.05	6.3	5.53	0	0	55	2.325
MoD4	low hills on coastal plains	3.025	3.525	4.125	6.237	5.337	0	0	59.384	1.143
Od	flood plains on river valleys on coastal plains	0.1	3.1	15.3	32.3	16.5	0	0	18	1.358
Sn	coastal plains, flood plains on river valleys	1.276	2.95	6.818	31.653	15.549	8.21	8.86	34.384	1.129

Observations based on aerial imagery and fieldwork were also indicative of changes to the riparian sedimentology. Recent sandy flood deposits were identified at locations along the riparian zone's study site, indicating changes to the Mission River's morphology.



Figure 4. Photo taken on February 19, 2018. A point bar sand deposit along a meander near FR-25 in the northernmost region of the study site. This flooding formation, approximately 14 km from the river outlet at Mission Bay, is distinctly composed of coastal sands.



Figure 5. Dead and downed vegetation dam Dry Creek at its confluence with Mission River, nearby the northernmost sampled site FR-25.

Analysis of aerial imagery input into a GIS environment also displayed changes to the Mission River's hydrological regime resulting from flooding events. Dead and downed vegetation following Hurricane Harvey's landfall was prominent in the study area, including the initiation of what might evolve into a natural levee.

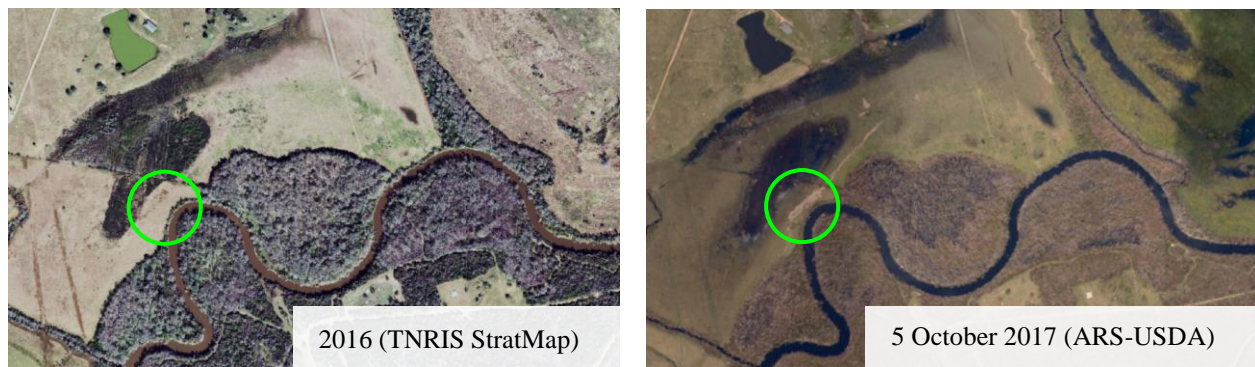


Figure 5. Aerial imagery taken before and after Hurricane Harvey's landfall. The identified feature shown is an early flood deposit formation of a levee after this event, located near a cut bank of a meander of the Mission River near site FR-12.

CHAPTER IV

CONCLUSION AND DISCUSSION

Human Impact

The design and results of this study made no indication of significant human impact within the area of study. Though cattle grazing could potentially contribute to erosional processes, management practices may also reduce these impacts. Visual identification of sampled horizon layer cores generally agrees with previously-obtained SSURGO data; however, the heterogeneous characteristic of the riparian zone's sedimentology and profile was not accounted for in the NRCS source, thereby contributing to potential sources of error. Furthermore, SSURGO data also indicated variation of soil composition based on county line demarcations between Refugio County, Victoria County, and Goliad County. The site of study was incorporated within the boundary of Refugio County; however, discontinuities among counties in this data set may have presented a source of error.

Flooding Events and Hurricane Harvey

It can be concluded that frequent flooding dominates the Mission River's hydrological regime – an observation that is evident in the abundance of flood deposits in the sampled horizon layer cores from various locations along the riparian zone. This conclusion also agrees with previously-referenced studies conducted in this area based on vegetation sampling and official reports local to Refugio County. Additionally, recent fine sand deposits found in surface sediments may also be indicative of the flooding event associated with Hurricane Harvey's landfall and progression within the Mission River basin. Dead and downed vegetation, thereby

resulting in a lower density from the hurricane event may also contribute to erosional processes in the future.

Other factors that may be considered in future studies of riparian sediments may include the consideration of fluvial morphology and topography characteristic of a coastal meandering river. These aspects are also influenced by the river's hydrological regime and determine inundation patterns and characteristics of the floodplain. Methods used to chronologically identify the progression of flooding events and/or resulting sand deposits may also be utilized to better-understand flooding and hurricane-caused changes to the Mission River basin.

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